How Can Architecture Improve the Health of Honeybees?

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"We shape our buildings and afterwards, our buildings shape us." —Winston Churchill in a speech to Parliament, 1943.

While Churchill may have been speaking about social dimensions of design for the House of Commons, his words foreshadow a challenge to Charles Darwin's Standard Evolutionary Theory. Conrad Waddington and Richard Lewontin introduced a new model of biological evolution, Niche Construction Theory (NCT) in the late 1980s that suggests species do not evolve purely through natural selection. In Niche Construction Theory, organisms direct their own evolution through intentionally modifying their environment:

"The organism influences its own evolution by being both the object of their own natural selection and the creator of the conditions of that selection."

NCT proposes that niche building organisms can intentionally modify the selection pressures that affect the genetics of future generations. Over time, niche constructing organisms create an ecological inheritance that shapes the genetic trajectories of future generations. The evolution of our built environment should also be considered a shared experience. In this project, we designed an architectural response to a very specific ecological niche, one that has been co-constructed by humans and honeybees. (Figure 1)

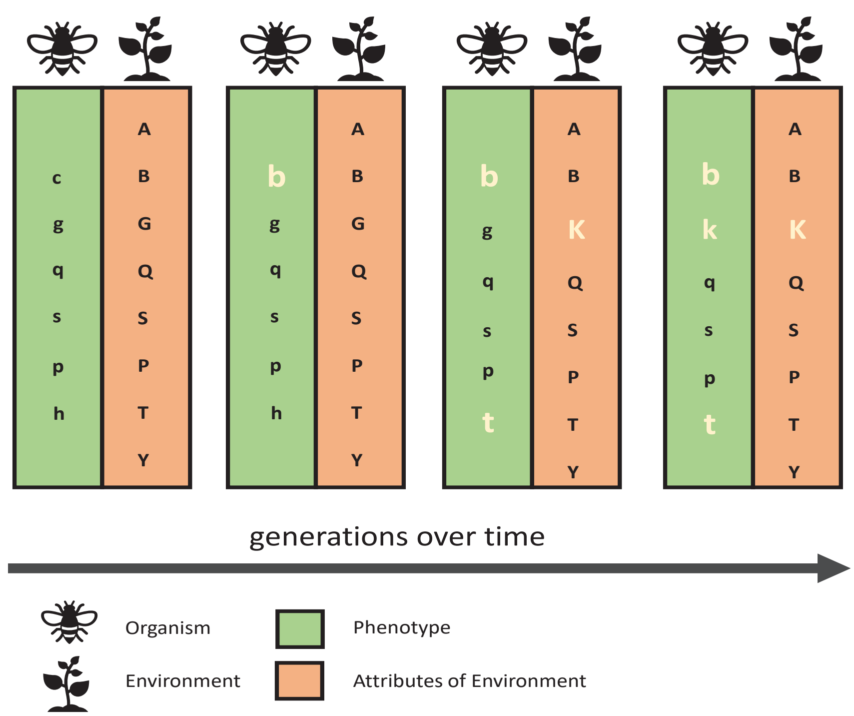

Figure 1. Diagram of Niche Construction Theory illustrating how niche building organisms alter the selection pressures in their environment over time, how the environmental selection then alters the phenotype in subsequent generations. Adapted by Author.

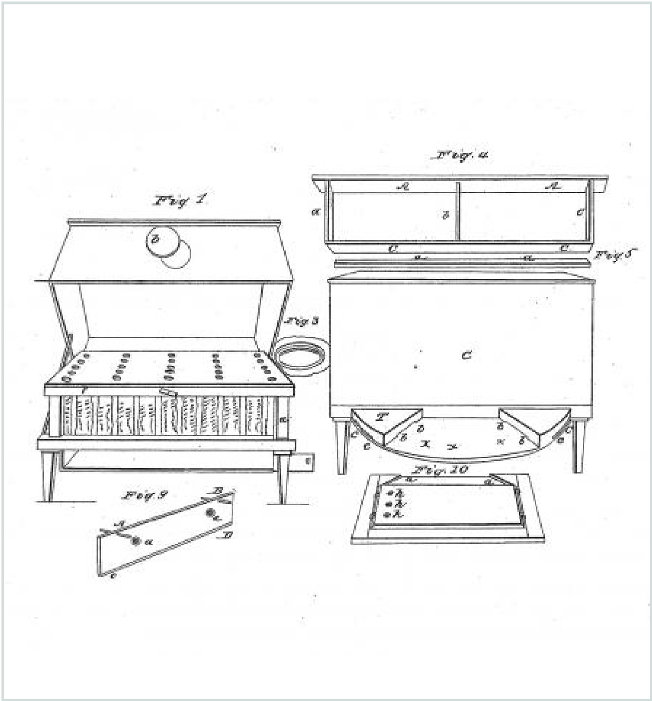

Figure 2. Langsthroth US Patent Drawing. https://patents.google.com/patent/US9300.

Figure 3. A typical 6 colony commercial pallet configuration. Photo by Author.

Figure 4. Currently, honeybees are transported across the US to pollinate crops as they bloom. Photo by Melissa Lyttle, Earth Justice.

Figure 5. Domesticated European honeybees inside a commercial hive. Photo by Daniel Rubenstein.

Both humans and honeybees share a trait that has contributed to successful niche building - both use dwellings as extensions of their own physiology. Dwellings take over some of the work of homeostasis for the organism. For example, humans have designed dwellings that both actively and passively manage the indoor environment to achieve a narrow range of thermal comfort. Honeybees are cavity dwellers who actively find, construct, then manage their internal environment by thermoregulating as a colony. The history of honeybee domestication and the co-creation of a niche is tightly wound around the design of human built housing for honeybees. Humans, through their knowledge of housing systems, have designed and managed honeybee housing for many centuries. The last novel innovation in housing came at the turn of the 20th century with the movable frame hive by R.L. Langstroth. (Figure 2) A version of Langstroth's design is the most used commercial hive today. (Figure 3) Not only has the design of dwellings for individual colonies not changed to meet a new climate, their communal housing also does not address the annual forced migration to mono-cropped landscapes nor the new community level interactions due to higher population densities. (Figure 4)

The current honeybee housing system is inadequate. It contributes to poor health, low survival rates, and the spread of disease. The human-centric instead off bee-centric design of their hive boxes leads to honeybees working harder to thermoregulate. Weather damage further compromises thermal integrity contributes to the growth of mold and bacteria. The overcrowding of honeybee colonies during migration to crops increases the spread of disease and competition for resources. High exposure to toxins lowers immune response and can have a lingering influence at a genomic level. These factors are confounded by climate change.

Climate change is already having a major impact on honeybee health. In the US, warmer fall temperatures have led to honeybees staying out longer in the environment to forage for limited resources. While they are out in the environment, they spread varroa mites and use up their honey stores that they would use over winter. Not only does this lead to higher varroa infestation therefore disease; it changes the demographics of the colony and impacts the development of next generation emerging in the spring.

When we viewed this situation through the lens of NCT, we considered the status of this niche to be maladaptive and questioned if it could be improved with a new housing design. To explore this further, we developed a hypothesis, "If we place colonies in a controlled winter environment that more

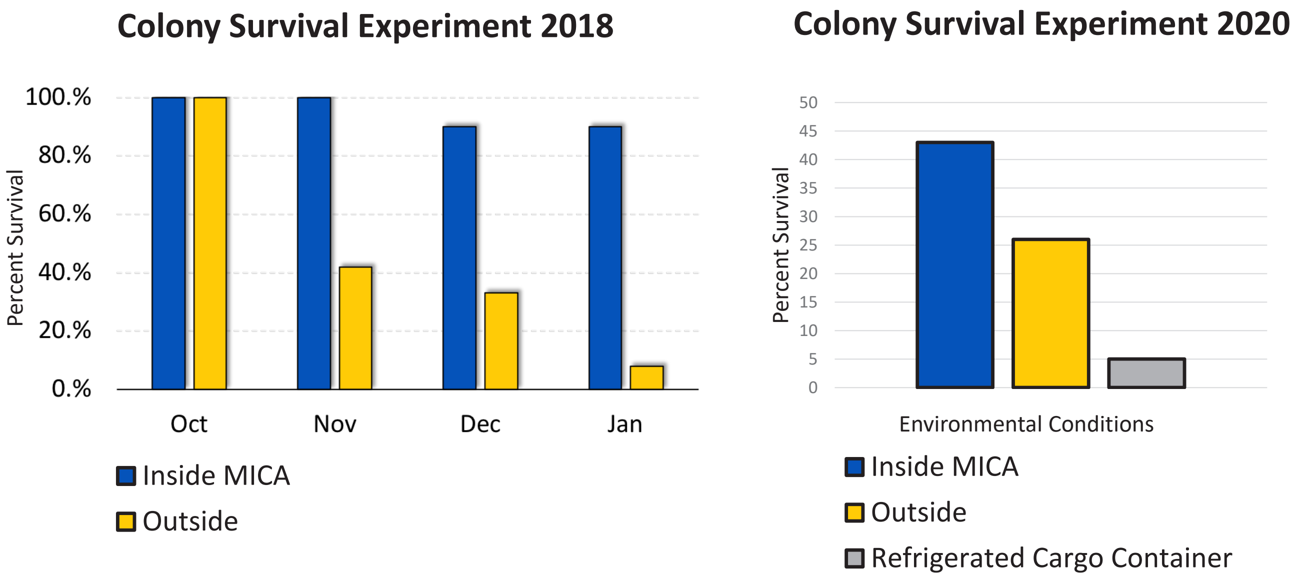

Figure 6 . Colony survival results from our two prototypes. Charts by Author.

Figure 7. A 96 colony capacity MICA traveling across the western United States. Photo by Author.

closely aligns with their biological evolution, can we reduce the spread of disease and preserve colony health?"

Driven by this hypothesis, our design process had three key elements:

1) "Place" based research about the organism and its habitat. Place based research focuses on the ecological and evolutionary life history of the organism and environmental interactions to establish baseline performance criteria for the architecture. In this situation, we decided to recreate an evolutionary state that the European honeybee would have encountered during the winter season prior to being imported into the United States. At this time in their evolution, the European honeybee (Figure 5) would have spent the winter inside the hive. Honeybees evolved to reduce their activity and store honey so that they could sustain the colony inside during the winter. Winter survival is the reason bees produce honey. We decided to recreate a similar environment to induce a hibernation state.

2) A testing method that evaluates the performance of architectural prototypes based on the health and survival of the organism. The assessment includes measures of "satisfaction," or the degree to which the architecture enhances the health and well-being of our organismal clients. We conducted two separate common garden experiments. The first experiment had two treatment groups – an inside group and an outside group. Our primary metric was survival rates. We used health assessments developed by the USDA to grade colony health before the winter and again after the winter.

3) Prototyping and replication. We designed built and tested two separate prototypes to validate our results and improve not only the health of honeybees, but to also improve the management practices of beekeepers. Through iteration and conversation, we gained an understanding of the complex interactions between honeybees, their housing needs, the constraints of the US food production system, and the challenges of human management practices. Our first prototype was a 12-colony unit that we used for a proof-of-concept test in the winter of 2018 in Boulder, CO. The result (Figure 6) was a 72% increase in survival rates for honeybees staying inside our unit for the winter as compared to colonies wintering outside. Based on this proof-of-concept prototype, we created a larger, more robust prototype with more sophisticated HVAC design and data collection system. Our second prototype (Figure 7) was a mobile, modular, indoor, climate-controlled apiary (MICA) to meet the needs of commercial scale beekeepers in various locations across the country. MICA was designed to hold 96 colonies and be driven to different environments for testing. In the winter of 2020, MICA was tested in Othello WA. In this test, we compared MICA's performance to outside colonies and colonies inside a refrigerated cargo container. Colonies inside MICA had a 43% survival rate. Colonies outside had a 26% survival rate. The refrigerated cargo container had a 5% survival rate. (Figure 6)

The result of this approach is a targeted reconstruction of the human and honeybee niche. We have found that designing a new dwelling that is more closely aligned with honeybee physiology improves winter survival rates. Designing a dwelling that makes management practices easier in a more complex world can also improve the human experience. As our climate changes, niches that humans have created with other organisms are going to become dysfunctional and architects can play an important role in their reconstruction. Folding an understanding of evolution and biology into the design process will allow architects to design for the many organisms that share our built environment. We are continuing our work with beekeepers and the USDA to bring this technology to the field.

ENDNOTES

1. Levins R, Lewontin RC., The Dialectical Biologist. Cambridge: Harvard University Press. 1985. p109.
2. Laland, K., Matthews, B., & Feldman, M. W. An introduction to niche construction theory. Evolutionary ecology, 30(2), 2016, p191-202
3. Adapted from Odling-Smee, F. John (2009). "Niche Construction in Evolution, Ecosystems and Developmental Biology". In Barberousse, A.; Morange, M.; Pradeu, T. (eds.). Mapping the Future of Biology. Dordrecht: Springer.
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